A synopsis of the thesis submitted in partial fulfilment of the requirements for the

DEGREE OF DOCTOR OF PHILOSOPHY IN FOOD SCIENCE AND NUTRITION

IMPACT OF LIFESTYLE INTERVENTIONS ON NUTRITIONAL STATUS, PHYSICAL ACTIVITY AND SLEEP PATTERN OF OVERWEIGHT AND OBESE WOMEN OF 18 TO 25 YEARS DURING COVID-19

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INTRODUCTION

Health is referred as a “state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity” by the World Health Organization (WHO, 2023). According to the WHO statistics (2022), NCDs account for 74 percent of the world’s deaths i.e., 41 million deaths annually around the globe. Risk factors such as a person's background, lifestyle and the environment are known to increase the likelihood of certain NCDs. According to the WHO (2022), to lessen the impact of NCDs on individuals and society, a comprehensive approach is needed requiring multiple sectors, including health, finance, transport, education, agriculture and planning to collaboratively reduce the risks associated with NCDs, and promote interventions to prevent and control them. Although there are genetic, behavioural, metabolic and hormonal influences on body weight, obesity occurs when there is an intake of food in more calories than the ones burnt through normal daily activities and exercises. Researched risk factors of obesity include socio-economic status, environmental factors, inter-uterine exposures, the genetic pre-disposition, perinatal antibiotic exposures, stress and most recently, covid-19 (Mohajan & Mohajan, 2023).

Obesity in adults according to the WHO classification puts the BMI cut-off at greater than or equal to 30kg/m^2 for non-Asians while the Asians, have it at greater than or equal to 25kg/m^2 (Dhawan & Sharma, 2020). In its factsheet, the WHO says that global obesity trends have nearly tripled since 1975. In 2016, more than 1.9 billion adults, aged 18 and above were overweight. Of these over 650 million were obese i.e., 39 percent of adults aged 18 years and over were overweight and 13 percent were obese. As per the WHO, most of the world's population lives in countries where overweight and obesity causes more mortality as compared to underweight (WHO, 2021; World Obesity Federation). In India, the prevalence of adiposity has been on an increasing trend from 19.75 percent in 2016 to 23.45 percent by 2021. Among this, exclusively among women obesity has increased from 20.6 percent to 24.0 percent between the ages of 15 and 49 years. A much higher increase than that of the national average was seen in the men and women belonging from Tamil Nadu. Almost eight to nine percent increase was observed in both the genders, an 8.8 percent difference in men and a 9.5 percent difference in

women from 28.1 to 37.35 in men and 30.8 to 40.75 in women (Indian Institute of Population Sciences (IIPS-ICF), 2017, 2021).

In recent years, an abundance of research has shed light on the importance of physical activity in the prevention and management of obesity. Physical activity is a vital component of energy expenditure, alongside basal metabolic rate and diet. Studies have confirmed that there is a dose-response relationship between physical activity and obesity. In other words, the more physical activity individuals engage in, the lower their risk of obesity (Ekelund *et al.,* 2019). Long-term success in weight loss maintenance is closely linked to continued engagement in physical activity (Recchia *et al.,* 2023). All these highlight the need for personalized physical activity strategies tailored to individual preferences and lifestyles and for designing effective interventions to promote physical fitness and prevent chronic diseases, assessing physical activity is crucial. One widely used questionnaire is the Global Physical Activity Questionnaire (GPAQ), developed by the WHO in 2012. GPAQ is preferred owing to its non-dependence on subjects' recall, global standardization (available in multiple languages, making it applicable to diverse populations across the globe), simplicity (relatively simpler consisting of a shorter set of questions designed to be administered in about 10 to 15 minutes), and focus on domains (three main domains of an individual's lifestyle - work, transport, and recreational activities). Sleep patterns and obesity have also been linked in recent times where mounting evidence is proving that poor sleep quality and duration can significantly contribute to weight gain and obesity (Xu *et al.*, 2022). The Pittsburgh Sleep Quality Index (PSQI), developed by Daniel Buysse in 1989 has been used to measure self-reported sleep quality in different populations across the world and can be considered as an accepted reference or gold standard for self-perceived sleep quality (John *et al.*, 2022). However, even though establishing and maintaining healthy sleep patterns is crucial in obesity prevention and management, there is insufficient evidence in the Indian context, which calls for employing this aspect in the present study.

Diet is a major modifiable determinant of obesity, and it has already been established that diet quality, measured with data-driven dietary patterns and diet quality scores are linked to metabolic syndrome in young adults, regardless of their adiposity status (Osadnik *et al.*, 2020). Assessing diet quality can provide information

on dietary behaviours and ways to manage obesity through quality dietary intake. The present study employs food frequency questionnaires (FFQs) which are mostly used in studies assessing diet and disease associations, and single or multiple daily recalls i.e., 24-hour dietary recalls (24-HDRs) which are mostly used in nutrition surveillance studies to monitor the food intake of the population.

Presently, weight loss and other lifestyle changes are the first-in-line treatment of individuals with obesity since metabolic status and central adiposity have consistently predicted morbidity and mortality (Vlassopoulos *et al.*, 2021). The WHO is of the view that reducing the risk of overnutrition includes an approach combining diet and physical activity. WHO promotes that decreasing the number of calories consumed from the diet in terms of fats and sugars while increasing the intake of fruit, vegetables, legumes, whole grains and nuts daily is the way to go. The WHO in its guidelines that have been updated recently recommends that all adults aged from 18 to 64 years are encouraged to have a minimum of 150 minutes of weekly aerobic physical activities of moderate intensity (WHO, 2022). Similarly, in India, the Indian Council of Medical Research together with the National Institute of Nutrition (ICMR-NIN) recommends that a minimum of 30 to 45 minutes of physical activity of moderate intensity for five to six days every week (Indian Council of Medical Research-National Institute of Nutrition (ICMR-NIN), 2010; ICMR, 2020). Therefore, just as the current guidelines suggest, it is necessary that the effective management of obesity requires an outlook that includes strategies of behaviour change focusing on reduced dietary intake along with a rise in physical activity as early as possible (ICMR, 2020).

DEFINITION OF THE PROBLEM

Aware of how urgent it is to combat the global pandemic of obesity, academics and medical professionals have developed a variety of treatment approaches. The cornerstone of the battle against obesity is physical activity, which not only helps people burn extra calories but also enhances their general health and well-being. A balanced diet that lowers calorie intake while increasing the intake of foods with a higher nutritional value is essential for optimal nutrition. Combining these tactics and customizing them to each person's requirements can help fight obesity, promote improved health, and lower the risk of non-communicable diseases.

Defining the problem statement of the present study in this manner aims to extend the groundwork for a more thorough examination of overnutrition, especially obesity, and the non-invasive, individual-centric, behaviour change based approaches designed to address this widespread health concern.

OBJECTIVES

Objectives of the Study

The primary objectives of the study are to:

- Study the socio-economic status, dietary pattern, nutritional status and frequency of morbidities of 18 – 25 years old college-going women.
- Determine the nutritional status, physical activity levels, sleep quality, and the knowledge, attitudes and practices (KAP) of healthy lifestyles of these collegiate women.
- Develop aerobic exercise routines and nutrition education modules as interventions for the women based on their nutrition knowledge and health status.
- Assess the impact of intervention on the nutritional status, physical activity levels, sleep quality, and the knowledge, attitudes and practices of the selected women.

SCOPE OF RESEARCH WORK

Reduced access to nutritious food (which may be due to lack of awareness or lack of time on their hands) and declining levels of physical activity, along with urbanization, technological advancements, and rising economic stability of urban families that put an electronic device in the hands of most people, are contributing to the trend of obesity. Monitoring current developments in noncommunicable illnesses and the hazards associated with them is essential in order to develop policies, organize public health efforts, and make choices based on the most relevant information available. It is a crucial first step in improving population health including overall wellbeing and lowering the growing burden of noncommunicable illnesses. The world is experiencing overnutrition especially obesity on an epidemic turned pandemic scale with the prevalence of obesity being elevated in areas spanning national and international borders. Identifying probable causes of obesity is becoming important to build a secure and healthy future generation. It is in such a scenario that the future of the management of this global pandemic across all ages

and genders becomes essential. Therefore, the findings of the present study aim to provide non-invasive, individual-centric, behaviour change based solutions to individuals especially women, to overcome the possible health issues related to overweight and obesity; thereby pursuing a healthy future for the coming generations.

METHODOLOGY

The second wave of Covid-19, which ran from April 2021 to April 2022, was the period during which the longitudinal research study (Ethical Committee acceptance number: IHEC/19-20/FSN-38) was carried out among college-going women. Though initially planned for Coimbatore, due to the existing Covid-19 restrictions, samples were selected from the host institution. Participants who were women, who self-reported as being between the ages of 18 and 25, were going to college, had lived in Coimbatore for at least three years, and their initial body mass index (BMI) suggested that they were overweight or obese were included as participants of the present study. Sample size of the study was calculated utilising the formula as described by Daniel and Cross (2018), and Liu *et al*., (2021) and determined to require at least 670 subjects.

As part of **Phase I** of the study, pre-tested and validated, structured survey forms and globally accepted questionnaires were determined to be used after obtaining necessary permissions. Surveys were developed by the researcher to gather information on the socio-economic status, anthropometric assessment, physical examinations, dietary habits, food consumption, and Knowledge-Attitudes-Practices (KAP) of study participants regarding the management of obesity. The questionnaires were tested for construct validity with feedback from 100 subject and non-subject experts and for reliability using the test-retest method, which was spaced one month apart. The Pittsburgh Sleep Quality Index (PSQI) questionnaire (Buysse *et al.,* 1989) was implemented to get information on the sleep quality of the study subjects, while the Global Physical Activity Questionnaire (GPAQ) (WHO, 2012) was utilized to gather data about physical activity. In **Phase II**, the age, educational attainment, living locations, family structure, income, and, if relevant, the age at which the participants were married were among the background details that were examined. Using the modified Kuppuswamy scales (Sood & Bindra, 2022),

socio-economic profiling was carried out by assigning the research respondents to one of five categories: higher, upper middle, lower middle, upper lower, and lower based on the family head's employment, education, and income. **Phase III** consisted of the data collection evaluating the nutritional status of the study subjects using the "ABCD" approach. The anthropometric parameters of the subjects' including their height (in m), weight (in kg), resultant BMI (in kg/m^2), waist circumference (in cm), hip circumference (in cm), resultant waist-to-hip (WHR) ratio were recorded using the standard methods of measurements as per ICMR (2020) guidelines and body composition parameters analysed through body impedance analysis pertaining to the subjects' skeletal muscle mass, percent body fat, basal metabolic rate and overall fitness score. Assessment of biochemical parameters of study subjects included conducting tests of random blood glucose, haemoglobin and thyroid function including serum triiodothyronine (T_3), thyroxine (T_4) and thyroid stimulating hormone (TSH) following the good clinical laboratory practice guidelines (ICMR, 2021). Clinical examination of the study subjects consisted of the researcher conducting the physical examination of the study subjects with the assistance of a qualified medical practitioner for physically observable signs and symptoms of diseases related to the hair, skin, eye, mouth, teeth, and musculature including nutritional oedema, problems with vision, texture of skin, anaemia, muscle wasting, oral health and dental hygiene etc. through a pre-tested checklist. Self-reported responses from subjects were used to detect the morbidity pattern up to 3 months prior to the study utilising a pre-tested questionnaire that included queries on covid, episodes of cold/fever, bouts of diarrhoea, nausea/vomiting and their frequency, whether subjects consumed medication for the above morbidities and the presence or absence of food allergies. Dietary pattern/preferences and food consumption were assessed by food frequency questionnaires, and 24-hour-recall (24HR) questionnaire. As for the indicators of their lifestyle, the data collected included their physical activity through the GPAQ, sleep patterns through the PSQI, and their knowledge, attitudes, and practices on managing obesity through a pre-tested and validated questionnaire. In Phase IV, the intervention methods to be used in the present study were identified and validated based on the data of the pre-study responses of the initial KAP survey. Firstly, nutrition education modules through PowerPoint presentations, posters focusing on general health, a calendar for the following year (2023) with positive messages were developed to be used along with nutrition counselling and secondly, online exercise

routines that could be followed by prospective study subjects were identified and subjected to pre-testing, approval and validation by a representative sub-sample population. **Phase V** included implementing the interventions aimed at lifestyle modifications of the study subjects. A computerized approach was used to randomly allocate patients into one of the four intervention groups, with a total of 158 subjects divided among the four groups. Since group zero consisted of the control group, no intervention was given to them. While subjects of experimental group 1 were imparted a physical activity intervention, subjects in experimental group 2 received dietary instruction and counselling and the third experimental group's subjects received a combination of nutrition education and counselling interventions in addition to physical activity. In **Phase VI**, after 26 weeks of the intervention period culminated, using the pre-tested and validated questionnaires as before the intervention, the study participants were evaluated once more for their eating habits, level of physical activity, sleep quality, and KAP. All 632 study participants' responses (or 164 sub-samples) were documented as post-intervention data by the end of the study period to be studied and interpreted by using the Statistical Package for the Social Sciences (SPSS) software's version 26 for Windows (SPSS Inc., Illinois, USA). To determine key or significant differences between the control and experimental groups for the implemented interventions, two significance thresholds of $p \leq 0.05$ and $p \leq 0.01$ were chosen.

ORIGINAL CONTRIBUTIONS OF STUDY

The key conclusions of the current study are summarised below:

- To validate the knowledge, attitudes and practices (KAP) questionnaire to be employed in this study, a pilot study was conducted among randomly selected 100 women, of which 50 had pre-requisite level of education in nutrition and 50 did not have any educational connection to the field of nutrition. The maximum number of pilot study participants came from the 24 to 25 years among the nutrition students while for the non-nutrition students, the highest number of participants came from the ages between 18 and 20.
- During the pilot intervention, the average scores of the students from the nutrition background ranged from 12.7 to 14.6, slightly, yet significantly increasing the total average scores to 40.4±0.71. Among the non-nutrition students, the average

scores ranged from 12.08 to 13.5 points, making the total average score to be 38.5±0.43 points, indicating the pronounced and significant improvement in the KAP of students from the non-nutrition background after the pilot intervention.

- Assessing the Cronbach's alpha (α) and the Pearson's coefficient (r) statistical correlations revealed that the pilot tested KAP questionnaire was found to have desirable levels of construct validity (0.87) and inter-reviewer reliability (0.90).
- A majority of the 632 women participants of the study belonged to the subjects who were 18 years of age (15%) while the least number of participants were 25 years old (10%), and were either pursuing (41%) or had completed (60%) the graduation. Most of the study subjects belonged to nuclear families (89%) with only 11 percent belonging to joint families. The maximum (56%) of the study sample belonged to the lower middle-income category while the minimum (21%) belonged to the upper middle-income category.
- On analysing the initial anthropometric parameters of the study subjects, it was seen that the average height of both the main and sub-sample subjects were significantly lower i.e., 1.56±0.34 m as compared to the standard while the average weight was higher by almost 10 kg. This in turn resulted in the average BMI also to be 26.23±1.11 kg/m^2 higher than the normal category as defined by the BMI cutoffs for Asians and the recorded WHR to be 0.88±0.15 confirming the presence of overnutrition in the selected women population.
- From the extensive initial body composition analysis, the average height of the sub-sample of the present study subjects was 1.56±0.002 m. The average weight was 64.77±0.32 kg, while the BMI was 26.32±0.75 kg/m^2 and the WHR was 0.88±0.001. Body impedance analysis revealed that the average Skeletal Muscle Mass (SMM) was 17.35±0.74 kg, the average Percent Body Fat (PBF) was 31.30±0.11 percent, the average Basal Metabolic Rate (BMR) was 1268.61±14.96 kcals and the average fitness score was 54.34±0.17 points.
- Assessing the initial Random Blood Glucose (RBG) levels of the sub-sample subjects showed that the average was 104.25±14.3 mg/dl while the average content of haemoglobin (Hb) was 11.73±1.05 g. Assessing the serum thyroid levels through the thyroid function tests revealed that the average levels of T3 was 100.89±3.53 ng/dl, T4 was 5.61±0.33 mcg/dl and TSH was 4.50±0.261 mc IU/ml.

- Outcomes of the initial clinical examination conducted for the sub-sample showed that tenderness of muscles was seen in 21.4 percent, xerosis or pigmentation of the cornea in 20.7 percent, and nutritional oedema was visible in 14.6 percent of the women. 10.3 percent did not have any observable symptoms at the time of the initial clinical examination.
- Assessing the initial morbidity pattern of all the women subjects revealed that the most common ailments were cold or cough (33%), fever (37%), vomiting or diarrhoea (5.2%) and food poisoning (3.3%). Twenty-one percent of the study samples were not sick up to three months prior to the initiation of the study. Episodes of these morbidities occur as frequently as once in two months (41%) and once a month (25.8%) among the study population.
- Analysing the dietary preferences of study subjects, it was observed that while 88 percent did not have food allergies and 5.4 percent remained undiagnosed, 6.6 percent were diagnosed with fish allergies (1.4%), lactose intolerance (2.8%), and nut allergies (2.4%). The food preferences showed that 3.2 percent of the subjects were vegan, 47 percent were vegetarian, 22 percent were ovo-vegetarian and 27.8 percent were non-vegetarian. Among 64.7 percent of the subjects, a four-meal pattern was the most preferred while 23.9 percent consumed six meals on an average, every day.
- Based on the responses recorded from the initial twenty-four-hour recall questionnaires, considering the macronutrient intake, the average intake of energy among the study subjects was 2786.75±74.6 kcals, the average protein was 29.16±13.12 g, the average carbohydrate was 309.41±32.37 g and the average fat was 50.3±10.4 g. Considering the micronutrient intake, the average iron intake was 13.8±4.1 mg, the average calcium intake was 702.01±101.82 mg, the average vitamin A intake was 741.21±12.19 mcg Retinol Activity Equivalents (RAE), while the average thiamine intake was 1.21± 1.1 mg, the average riboflavin intake was 1.41±0.61 mg, the average cobalamin intake was 0.89±0.41 mg and the average total folate was 151.0±38.51 mcg and the average vitamin D intake was 8.3±7.25 mcg while the average vitamin C intake was 72.13±33.2 mg. Considering the overall calorie intake of subjects among intervention groups before the intervention for Group 0 was 2784.30±71.14 kcals, while it was

2787.13±73.36 kcals for Group 1. Group 2 had 2783.85±83.54 kcals while Group 3 had 2793.01±69.80 kcals.

- Analysing the exercise habits of the subjects at the time of study initiation showed 41.3 percent of subjects as not having regular physical activity, 35.1 percent as having physical activity 2-3 times a week and 23.6 percent as having daily physical activity. Outdoors (48.7 percent) rather than indoors (37.8 percent) was the more preferred area of exercise. Considering the preferred time of day to exercise, 44.5 percent preferred early morning, 32.8 preferred morning, 9.2 preferred evening and 0.2 preferred night, just before bed. Stretching (25 percent), walking (27.8 percent), yoga (13.1 percent), jogging (7 percent), cycling (7.6 percent) and dance (6 percent) were the types of exercises preferred by the subjects.
- The initial GPAQ scores of the study subjects across intervention groups revealed that the average for all the subjects was 316.34±8.28 while Group 0 it was 314.97±8.10 and for Group 1 it was 315.06±8.09. For Group 2, it was 319.11±8.04 and for Group 3 it was 316.23±8.30, all below the standard 600. The inter-group variability was insignificant (F=2.896; p=0.218).
- The initial PSQI scores of the study subjects across intervention groups showed that the average for all the subjects was 19.11±1.50 while for Group 0 it was 19.16±1.41 and for Group 1 it was 19.05±1.25. For Group 2, it was 19.14±1.22 and for Group 3 it was 19.07±2.0, all below the standard of 21 to 25 points. The inter-group variability was insignificant (F=0.206; p=0.892).
- The initial KAP scores of the study subjects across intervention groups revealed that the average for all the subjects was 12.51±1.71 while for Group 0 it was 12.46±1.67 and for Group 1 it was 12.41±1.67. For Group 2, it was 12.51±1. 97 and for Group 3 it was 12.70±1.70, all below the maximum score of 45. The inter-group variability was insignificant (F=0.874; p=0.454).
- The exercise routines were identified and tested among 100 women students aged between 18-25 where 50 percent of pilot study subjects had an educational background in physical education while the other 50 percent consisted of those who did not. Considering the screening of YouTube videos with selected exercise routines according to clarity of instruction, execution/demonstration and probability of compliance (30 points in total, 10 points each), the screening scores for video 1

and video 2 was 24.6 and 25.6 among the physical education students while it was 25.4 and 27.8 respectively for the non-physical education students, and video 2 was determined to have the greater acceptability.

- Analysing the validity and reliability of formulated exercise routines, it was found to have overall desirable levels of construct validity (0.88) and inter-reviewer reliability (0.90) among the physical education and non-physical education students. Analysing the validity and reliability of formulated nutrition education modules, it was found to have overall desirable levels of construct validity (0.80) and inter-reviewer reliability (0.82) among the nutrition students while it was 0.85 for both construct validity and inter-reviewer reliability among non-nutrition students. The overall construct validity and inter-reviewer reliability was 0.90 for both nutrition and non-nutrition students.
- Considering the anthropometric parameters of the study subjects after intervention, the average weight of the subjects was 59.54±5.13 kg, while the average BMI was 24.27±1.81 kg/m^2 and the average WHR was 0.83±0.28. Group 0 did not have statistically significant changes in their anthropometric parameters while Group 1 subjects saw a 7 kg weight loss and 3 kg/m^2 loss of BMI. Group 2 subjects saw a 4 kg weight loss and 2 kg/m^2 loss of BMI and Group 3 subjects saw a 9 kg weight loss and 4 kg/m^2 loss of BMI. The WHR was a consistent 0.06 point reduction in the experimental Groups 1 and 3 while it was a 0.04 point reduction in Group 2. All the differences were statistically significant across the intervention groups.
- Among the study sub-subjects after intervention, in body weight, there was an average decrease of 8 kg in Group 1 while there was an average decrease of 4 kg in Group 2 and an average decrease of 9 kg for Group 3. In BMI levels, there was a statistically significant difference of 2.92 kg/m^2 in Group 1, 1.53 kg/m^2 in Group 2 and 3.48 kg/m^2 in Group 3. Considering WHR, there was a statistically significant difference of 0.06 in both Group 1 and Group 3 while it was a 0.02 difference for Group 2. In the SMM parameter, there was an increase of 2.49 kg in Group 1, and a 2.56 kg increase in Group 3, there was no change in Group 2. Observing the PBF levels, there was a decrease across all the intervention groups, 4.05 percent in Group 1, 2.08 percent in Group 2, and 4.91 percent in Group 3. Considering BMR levels, there was an increase of 59.07 kcals in Group 1, a decrease of 33.76

kcals in Group 2 and an increase of 91.54 kcals in Group 3. The average fitness scores of Group 1 increased by 27.39, while the increase was 28.29 for Group 3.

- Biochemical assessment of sub-subjects after intervention revealed that the average RBG levels was 107.39±14.2 mg/dl while it was 15.06±2.98 g of average Hb, 88.81±2.31 ng/dl for average T3, 4.67±0.46 mcg/dl for average T4, and 0.933±0.33 mc IU/ml for average TSH levels. The RBG levels in Group 1 was higher than the pre-study data by 3.3 mg/dl, while it was higher by 2.5 mg/dl in Group 2 and 4.3 mg/dl in Group 3. In Hb, there was also an increase of 0.42 g in Group 1, 2.08 g increase in Group 2, and a 2.1 g increase in Group 3. As for the T3 levels, there was a decrease of 12.55 ng/dl in Group 1, 12.6 ng/dl in Group 2 and a 13.85 ng/dl decrease in Group 3. In the T4 levels, there was a 1.02 mcg/dl decrease in Group 1, 1.1 mcg/dl decrease in Group 2 and a 1.06 mcg/dl decrease in Group 3. In the TSH levels, decrease of 3.54 mc IU/ml in Group 1, a decrease of 3.55 mcg/dl in Group 2 and a 3.58 mc IU/ml in Group 3 and the differences in between groups were statistically significant.
- Examining the clinical symptoms of study sub-sample after intervention revealed that 38 percent of the subjects did not have any of the symptoms by the end of the study period. 7.4 percent of the women reported a reduction or complete withdrawal in the tenderness of muscles. For mild anaemia, there was a 1.3 percent reduction, while nutritional oedema decreased from 10.9 percent to 10.3 percent, corneal pigmentation was reduced by a 4.3 percent, angular stomatitis or angular cheilitis also reduced by a 2.4 percent, glazed tongue was reduced by a 2.4 percent, bleeding gums was reduced by 4.3 percent, dental caries, skin pigmentation decreased by a 0.2 percent each and rough skin reduced by 1.8 percent.
- Assessing the post-intervention morbidity pattern for the entire study sample revealed that there was an improvement in the episodes of morbidity (47.9 percent), especially food poisoning (0.8 percent) among the study participants after the study period. A marked improvement was also seen with respect to how the frequency of the above-mentioned morbidities occurred less (35.8 percent) in the months following the intervention.
- Considering the average final macro-nutrient intakes of the subjects, the energy consumption was 2314.16±31.91 kcals, the protein consumption was 43.12±27.1

g/kg body weight, the carbohydrate content was 238.24± 23.5 g, and fat intake was 43.27±19.2 g. In the average final micro-nutrient intakes of the subjects, iron intake was 16.21±2.14 mg, calcium intake was 763.0± 45.41 mg, vitamin A intake was 832.51± 92.19 mcg RAE, thiamine intake was 1.7±0.26 mg, riboflavin was 1.65±0.21 mg, and cobalamin was 1.8±0.13 mg. Vitamin D intake was 18.12±3.13 mcg while vitamin C intake was 68.87± 23.54 mg.

- Energy consumption had reduced by 243 kcals in Group 2 and about 394 kcals in Group 3. There was an 18 g increase in Group 2 and a 12 g increase among Group 3 of protein. In terms of carbohydrates, there was a decrease of about 22 g in Group 2 and a decrease of about 13 g in Group 3. The amount of fat consumed decreased by 20 g in Group 2 and by 6 g in the third intervention group. Dietary iron intake had gone up by by 2.8 mg for Group 2 and by 3.7 mg in Group 3. Dietary calcium intake had increased by 89 mg in Group 2 and by 78 mg in Group 3. Considering the dietary intake of vitamin A, it was up by 89 mcg RAE in Group 2 and by 78 mcg RAE in Group 3. Thiamine increased in Group 2 and Group 3, by 0.27 and 0.47 mg respectively. Riboflavin increased by 0.24 mg in Group 2 and 0.23 mg in Group 3. For cobalamin, the intake increased by 0.84 mg in Group 2 and 0.89 mg in Group 3. The intake of TDF had also increased by 18 mg in Group 2 and by 20 mg in Group 3. For vitamin D, there was an observed 0.8 mg increase in Group 2 and a 1.4 mg increase in Group 3. As for the vitamin C, there was an increase of 1.9 mg in Group 2 and an increase of 2.5 mg in group 3.
- The GPAQ scores of subjects across intervention groups post-intervention showed that all the groups had 810.27±392.31 as the average. Group 0 had 314.58±7.93, Group 1 had 974.67±20.01, Group 2 had 651.71±30.20, and Group 3 had 1300.13±31.08. The differences between the control and experimental groups were significant when analysed with analysis of variances ($F=31.63$, $p<0.001$), with the highest difference being observed in experimental group, Group 3. There was an increase in subjects having the regular habit of exercise i.e., from 25.7 percent at study initiation to 86.6 percent by the end of the study period ($F=361.14$, $p<0.001$*).
- As per the final PSQI scores of the study subjects, there was a significant improvement ($F=35.85$, $p<0.001$) across all the intervention groups and the

average for all the subjects was 10.27±6.12. Group 0 had 19.14±1.38, Group 1 had 6.33±1.04, Group 2 had 12.11±1.55, and Group 3 had 3.52±1.06.

- The average KAP scores of the subjects' post-intervention was 31.06±11.05 points. For Group 0, it was 12.58±2.08 points, while for Group 1 it was 21.70±1.91 points, for Group 2 it was 35.11±2.35 points, and for Group 3 it was 44.84±6.24 points.
- Multiple regression analysis showed a 60 percent probability that educational awareness improved anthropometric parameters including a decrease in weight by nearly 2 kg, reduction in BMI by 2 kg/m^2 and reduction in WHR by nearly 3 points. There was a 77 percent likelihood that exercise improves SMM by 2.7 kg and BMR by 0.5 kcals. As a combined effect, there was a 42 percent chance that weight, BMI, WHR, and PBF could significantly decrease while SMM and BMR could increase ($F=19.56$, $p<0.001$).
- There was a 23 percent probability that the nutrition education intervention improved the haemoglobin content (by 2.70 g) as well as lowered the serum TSH (by 0.81 mc IU/ml) levels of the study subjects. A 31 percent of significant chance existed for 1.47 g of haemoglobin content to improve while the individual's TSH reduced by 2.41 mc IU/ml as a result of the exercise intervention. Combining both the interventions, there is a 48 percent likelihood that serum parameters including RBG, and thyroid function parameters would decrease while Hb would increase ($F=11.60$, $p<0.001$).
- There was a 12 percent chance that nutrition education significantly explains the 1.75 reduction in dietary intake and a 0.29 reduction in the sleep score. Exercise may explain both dietary intake and sleep scores to the extent of 81 percent, where there is a 0.87 reduction in the calorie consumption of food and a 5.48 reduction or improvement in the PSQI sleep scores. There was a 44 percent likelihood that both the interventions combined would significantly reduce dietary intake as well as improve the sleep quality of the study subjects ($F=247.37$, $p<0.001$).

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CONCLUSION

Physical activity and nutrition education interventions have demonstrated a significant and positive impact on the nutritional status, physical activity levels, and sleep patterns of overweight and obese women. These interventions in the present study involved a combination of 30-to-45-minute exercise routines and nutrition educational components. By encouraging regular aerobic physical activity i.e., for at least five days a week every day for at least six months, these interventions helped overweight and obese women reduce their excess weight, body composition indices, waist-to-hip ratios while increasing their serum haemoglobin levels, improving their thyroid function parameters, morbidity pattern, muscle-to-fat ratio, and boost their overall fitness. Simultaneously, the nutrition education aspect equipped participants with valuable information about the knowledge, attitudes and practices regarding the aspects of general nutrition including healthy exercising habits, healthier dietary modifications and cooking methods, portion control, balanced diets, and mindful eating, leading to healthier food choices and calorie consumption through improved food and nutrient intakes. Moreover, these interventions lead to notable improvements in sleep patterns among the over nourished women by promoting relaxation, reducing sleep disturbances and cultivating a more supportive environment for restful sleep and better sleep quality. Thus, combination of exercise and nutrition education serve as a multifaceted approach to tackle the complex issues of overweight and obesity in women, resulting in the women with over nutrition establishing healthier physical activity routines and dietary habits that may contribute towards an overall enhancement in their lifestyles and the potential for

long-term weight management by improving their nutritional status, increased physical activity, and better sleep quality.

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